Measurement of the π^0 Differential Cross-Section with CLAS and outlook into 12 GeV Hall C

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Michael C. Kunkel
on behalf of the CLAS Collaboration

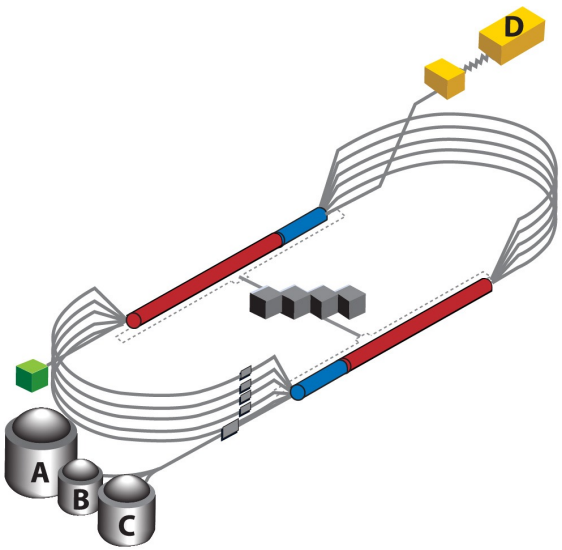
Motivation

- Reaction mechanisms, baryon resonances involved in π^0 production
  - For incident beam energies
    - Previously measured
    - Measurements where no data exists

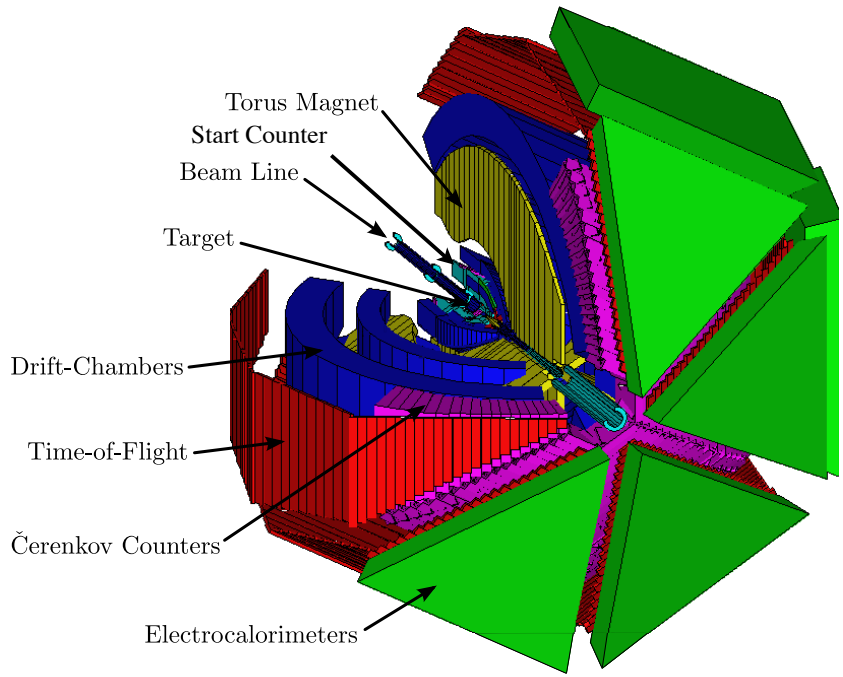
Goal

- π^0 cross-section
  - Compare to existing data
  - Compare to theoretical models

CEBAF Large Acceptance Spectrometer (CLAS)



Continous Electron Beam Accelerator Facility (CEBAF) at 12 GeV



CLAS

Primary modes of π^0 decay

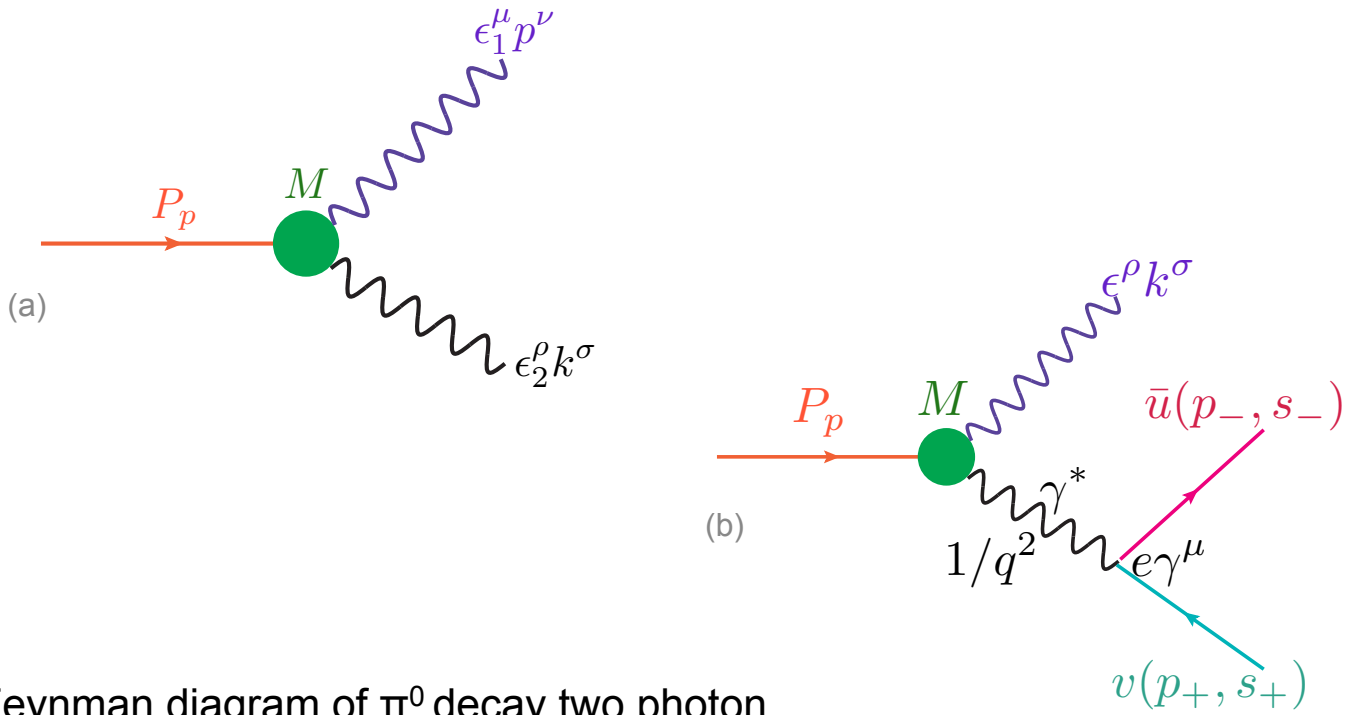
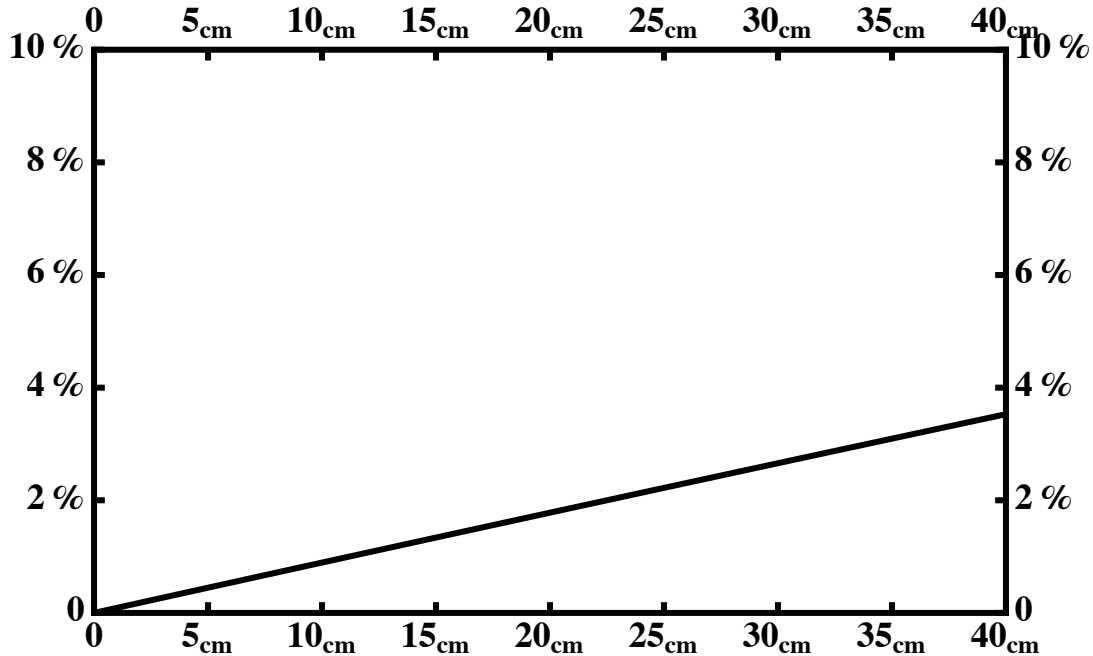


Figure: Feynman diagram of π^0 decay two photon decay (a). Feynman diagram of π^0 decay Dalitz decay (b).

External/Internal Conversion

- decays to γγ (98.823 ± 0.034)%
- π^0 decays to $e^+e^-\gamma$ 1.174 ± 0.035%

Total yield of π^0 using e^+e^- ~ 4.7% of total π^0 production



Probability of pair production, $\gamma \rightarrow e^+e^-$, in 40 cm of liquid hydrogen

g12 Overview

- Data was taken in Hall B. Experiment g12
- Running Time: 04/2008 - 06/2008
- 44 days of beam time
- 60-65 nA of current
- E_γ up to 5.5 GeV
- 126 TB Raw Data

- 26.2×10^9 production triggers (~5×10^9 events)
- 3×10^6 dilepton triggers (~3×10^6 dilepton events)
- EC and CC combine to provide π/e rejection factor of 10^{-6} for $e^\pm$ pairs

Data Selection

- Selection of beam photon
- 1 proton
- 2 oppositely charged tracks that are not proton

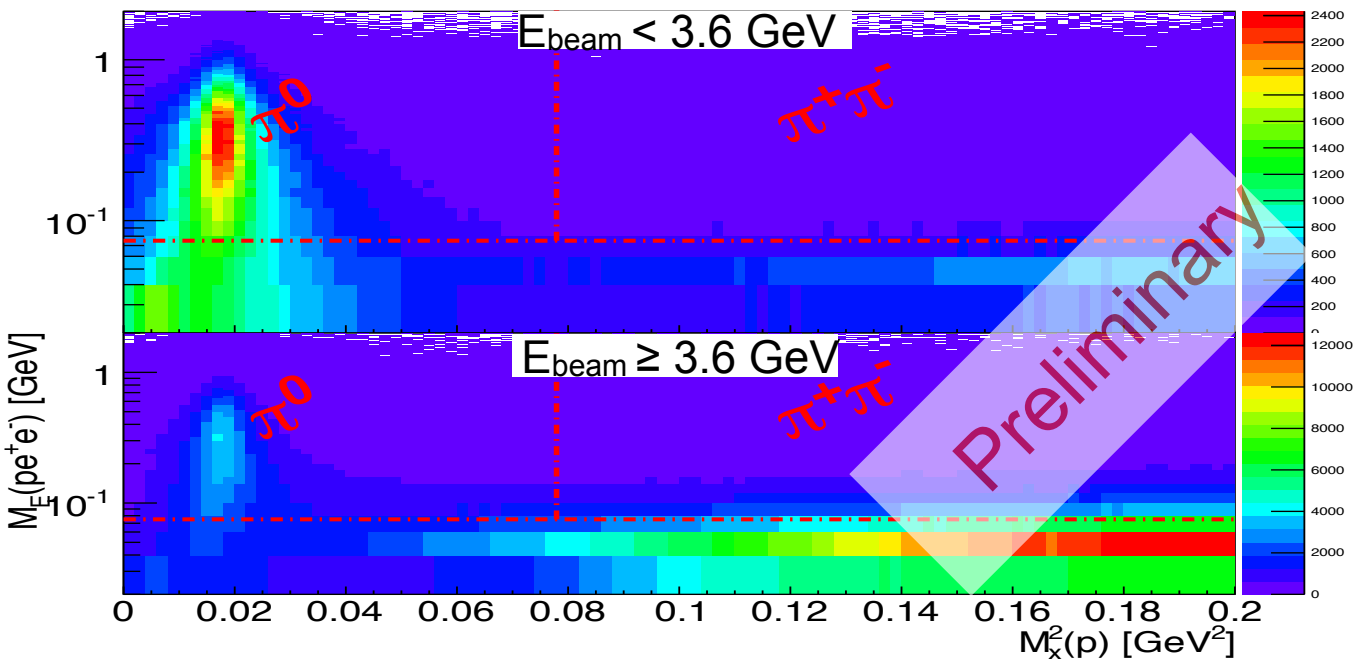


Figure : $M_x^2(p)$ vs. $M_E(pe^+e^-)$. The horizontal red dashed-dotted line depicts the 75 MeV cut used in this analysis. The vertical red dashed-dotted line depicts the boundary of single π^0 to $\pi^+\pi^-$ production.

Final π^0 Mass Spectrum

Data was kinematically fitted to missing photon

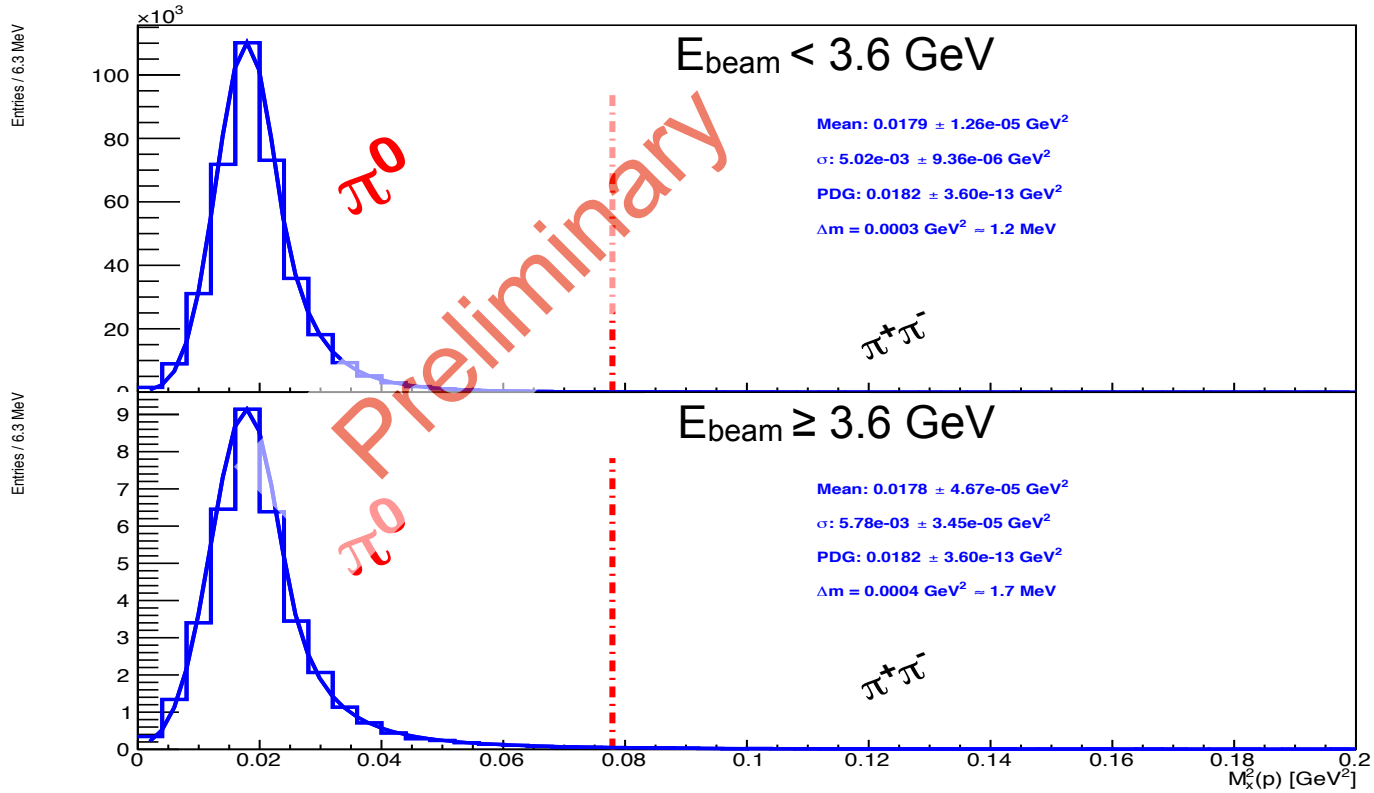


Figure : Final $\mathrm{M}_{\mathrm{x}}^{2}(\mathrm{p})$ data used in analysis.

E_γ = 1.275-2.225 GeV

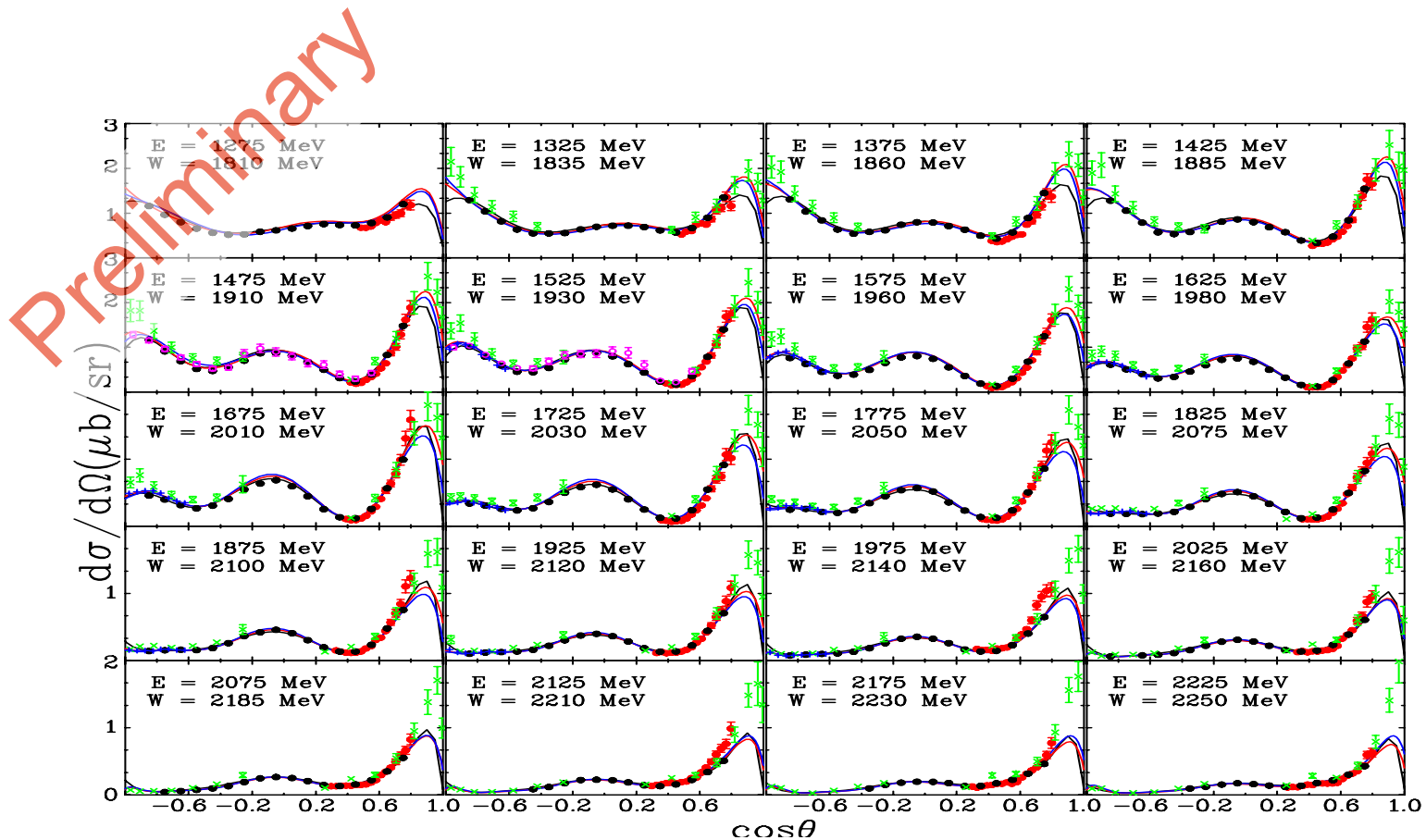
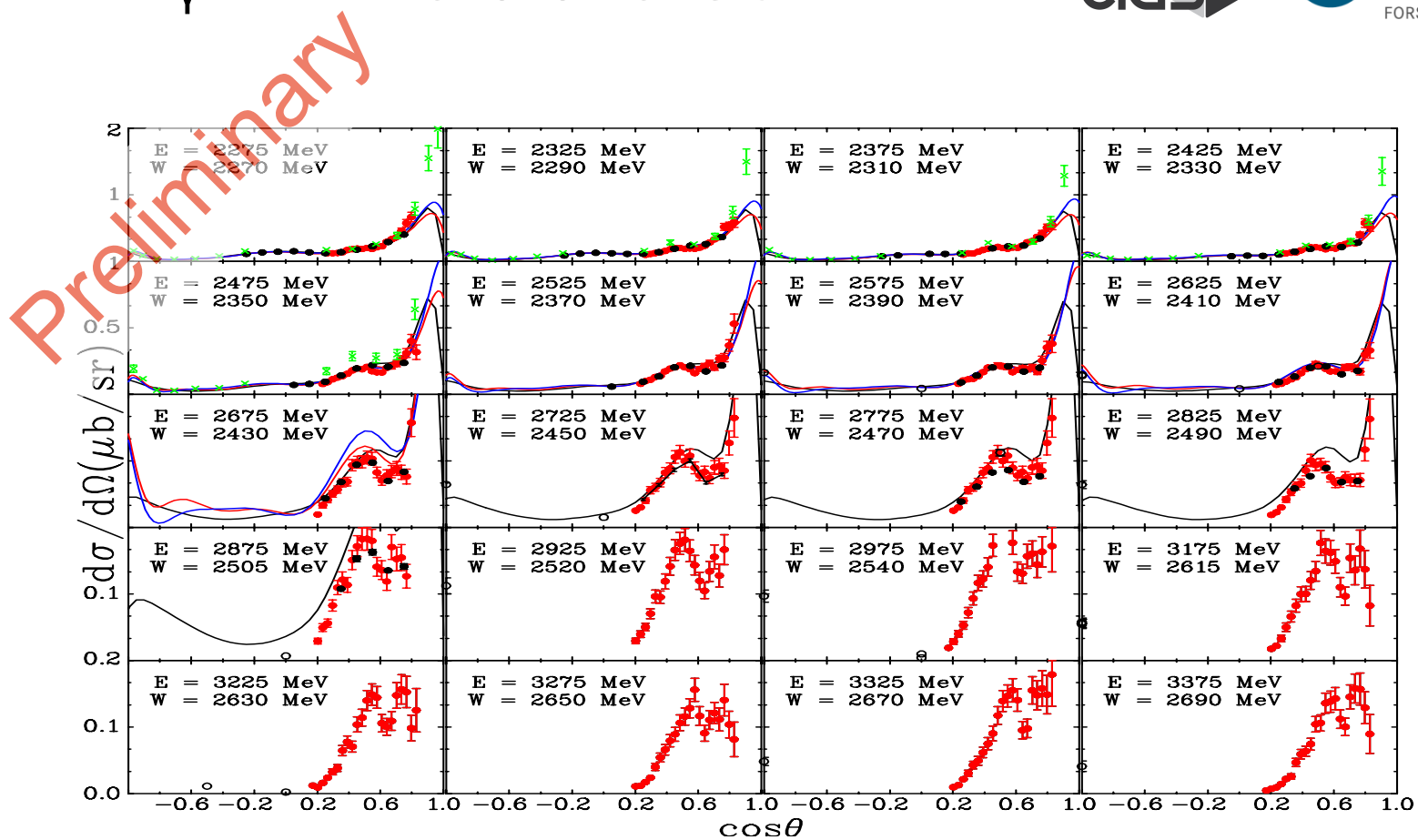


Figure : Red solid (blue solid) lines SAID KU14 (courtesy I.Strakovsky) (DU13) solution. Black solid lines BG2011-02 BnGa predictions. This work (red filled circles), previous CLAS (black filled circles), GRAAL (magenta open circles), LEPS (blue plus), CB-ELSA (green crosses). Previous bremsstrahlung measurements (black open circles)

E_γ = 2.275-3.375 GeV



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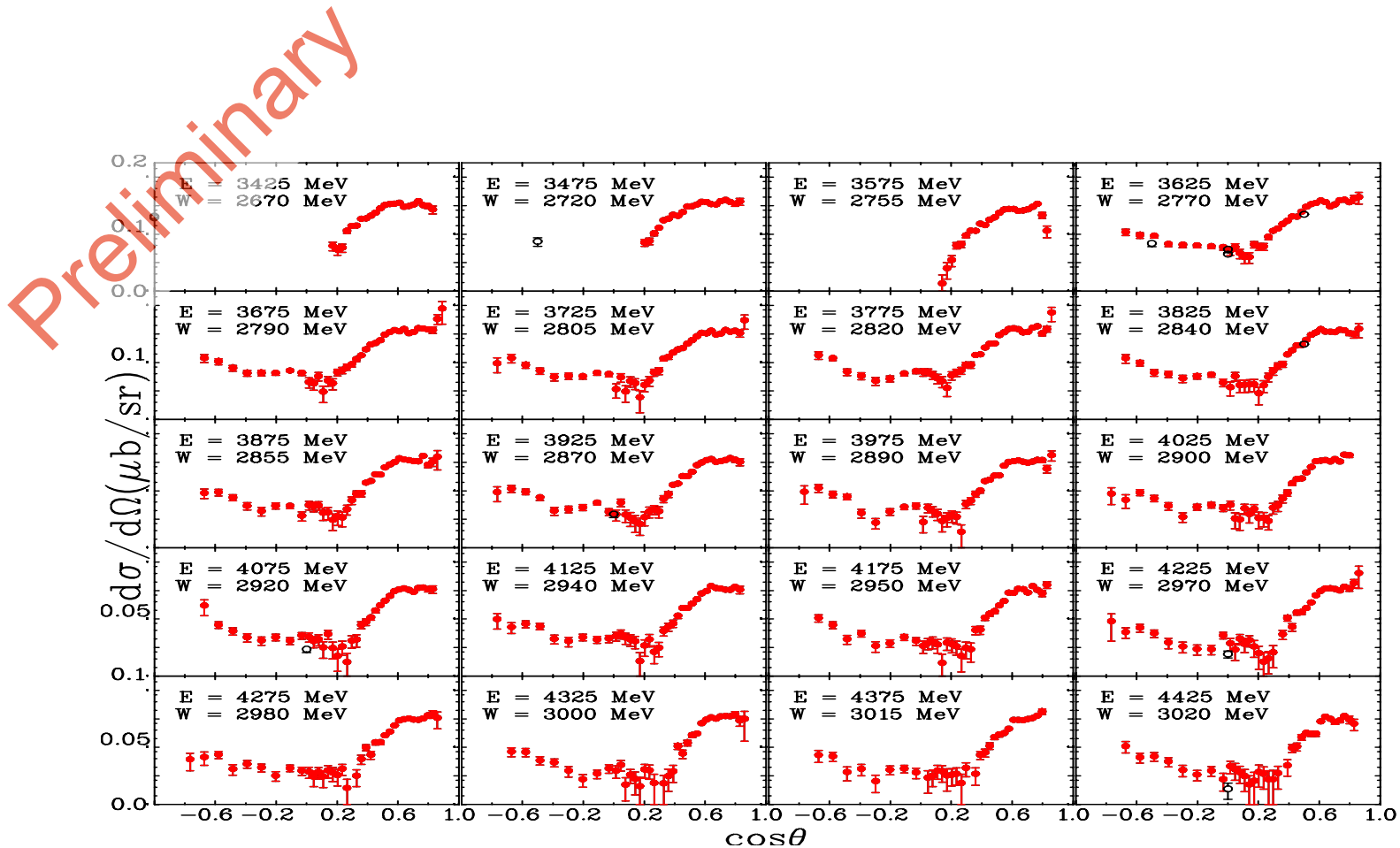
E_γ = 3.425-4.425 GeV



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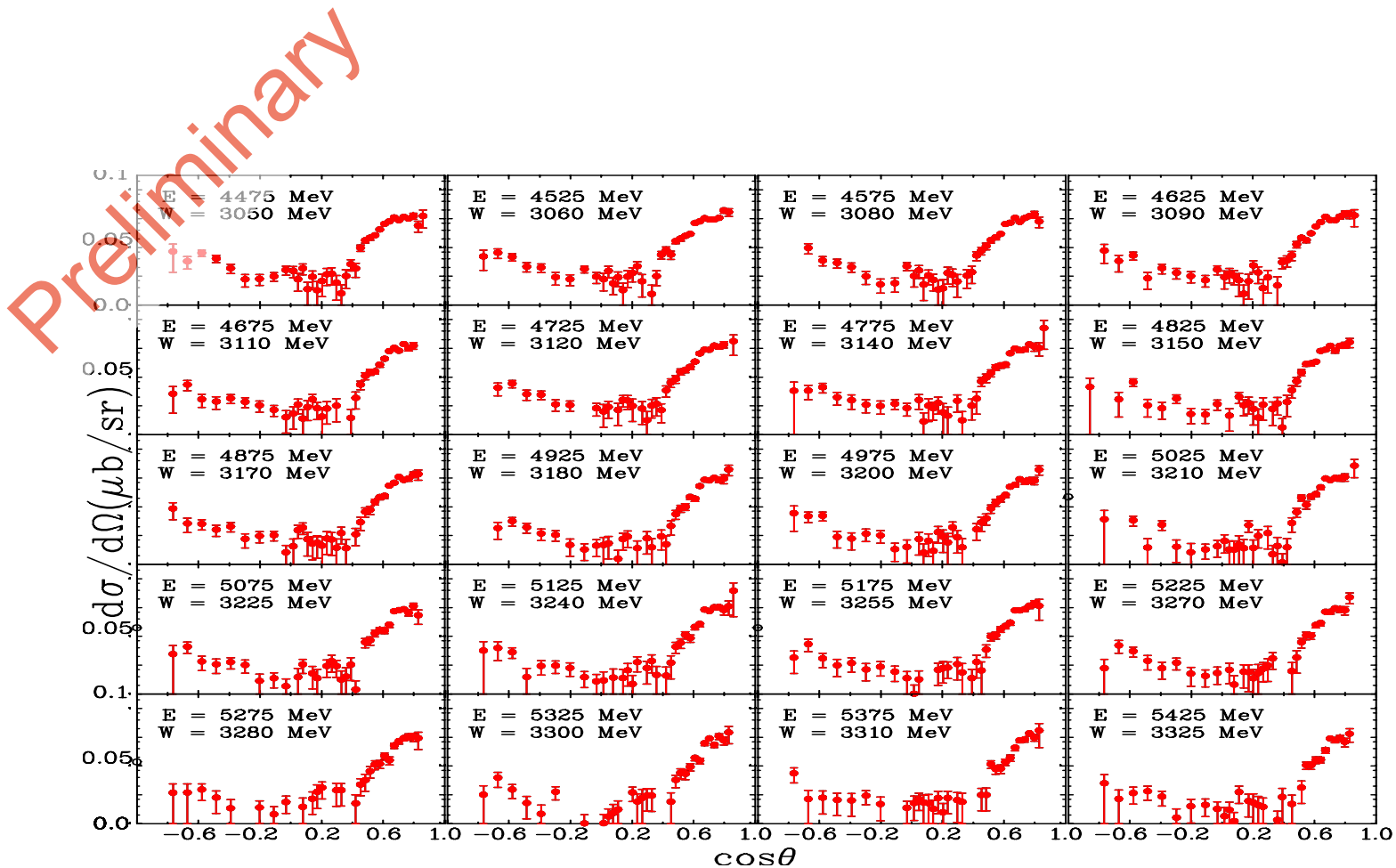
E_γ = 4.475-5.425 GeV



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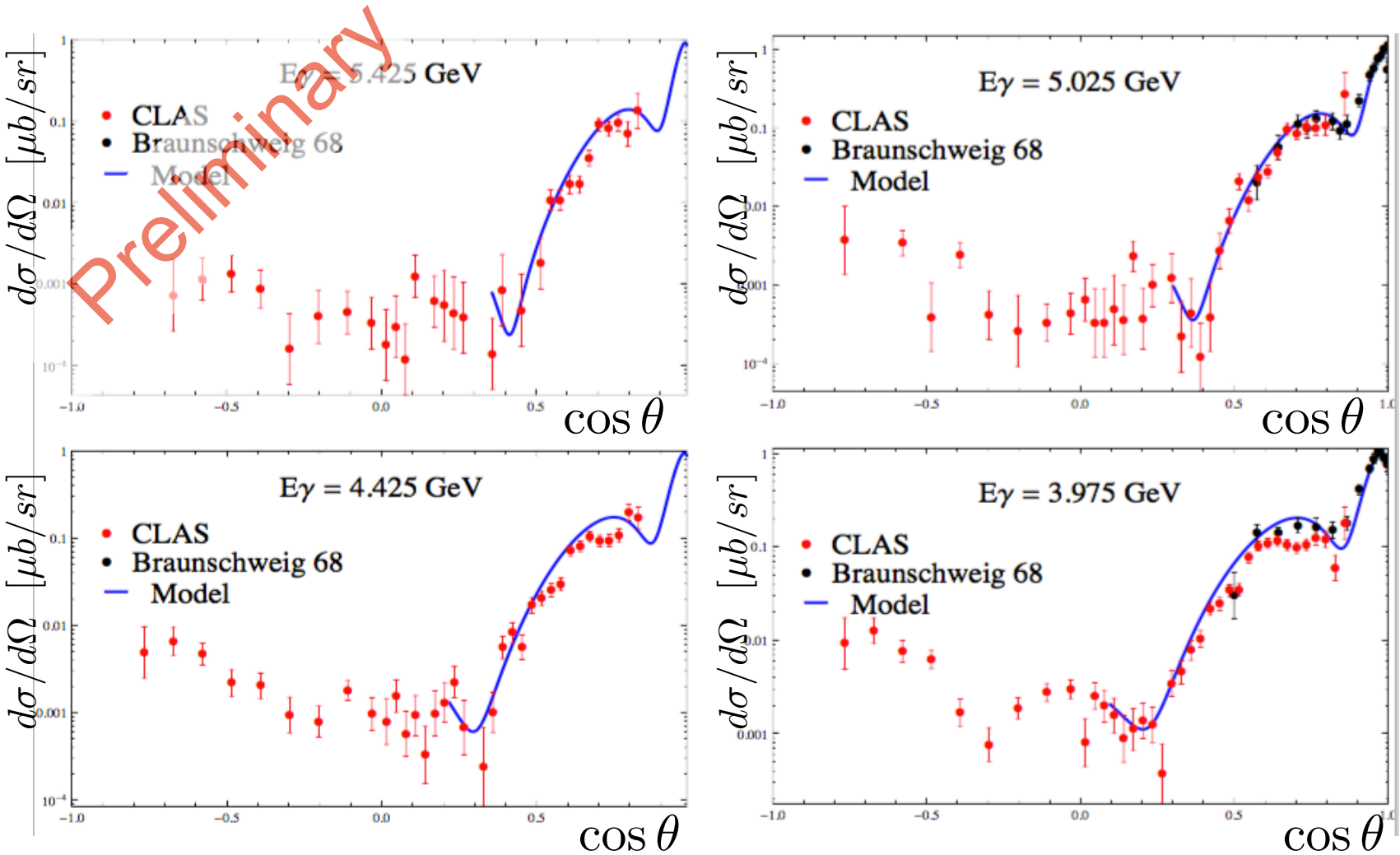
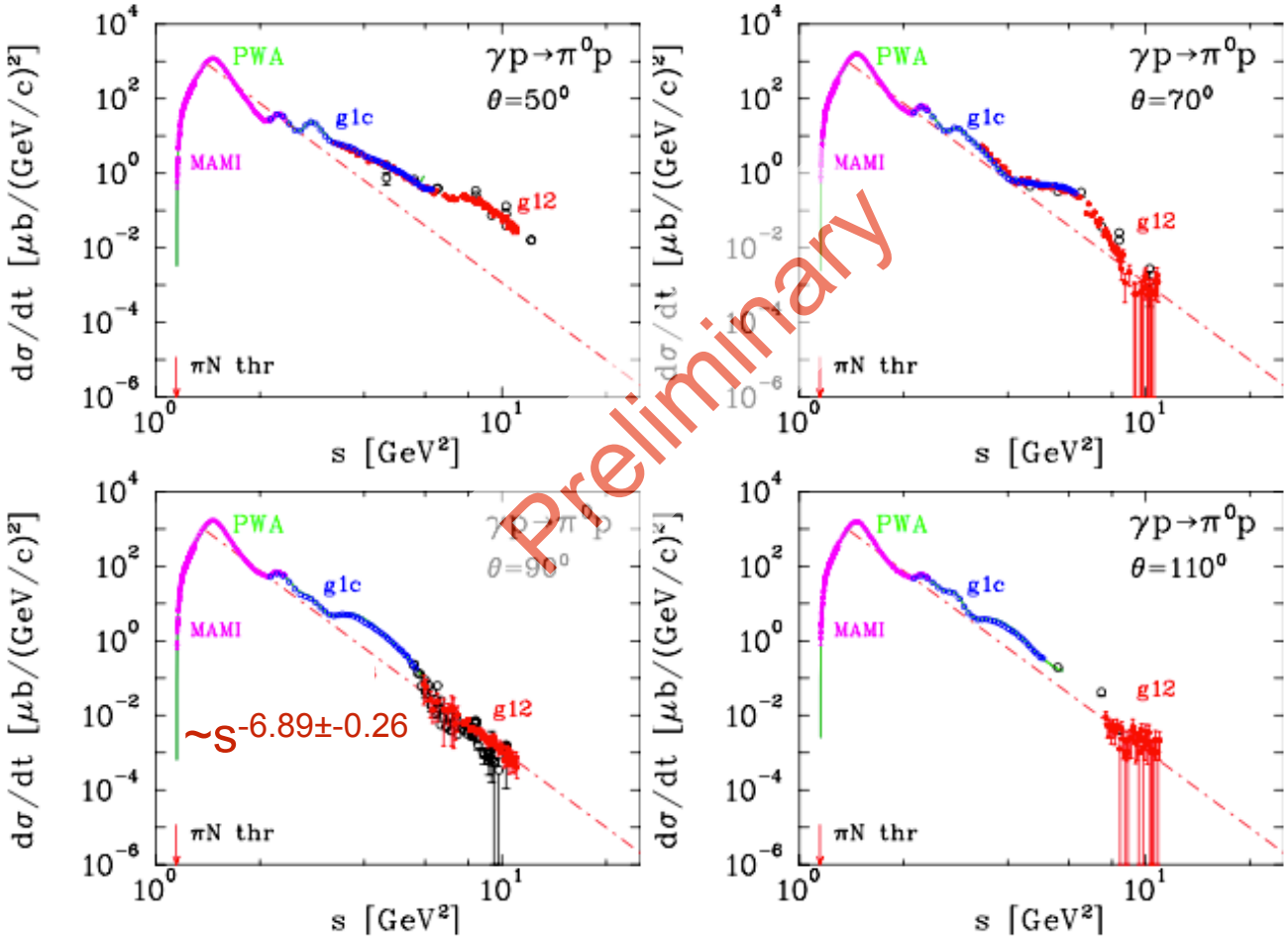
Neutral Pion Photoproduction in a Regge Model



[1] arXiv:1505.02321v1 [hep-ph] 9 May 2015.

Constituent Counting Rule



$$d\sigma/dt = h(\theta_{cm})/s^{n-2}$$

π^0 production in Hall C at 12 GeV

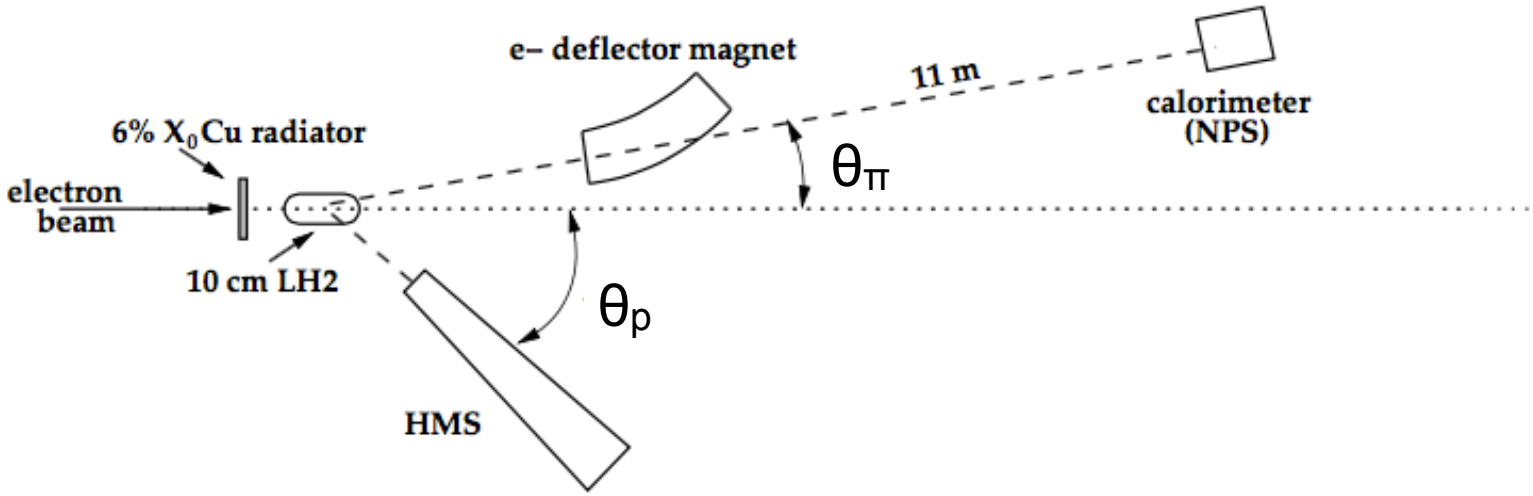
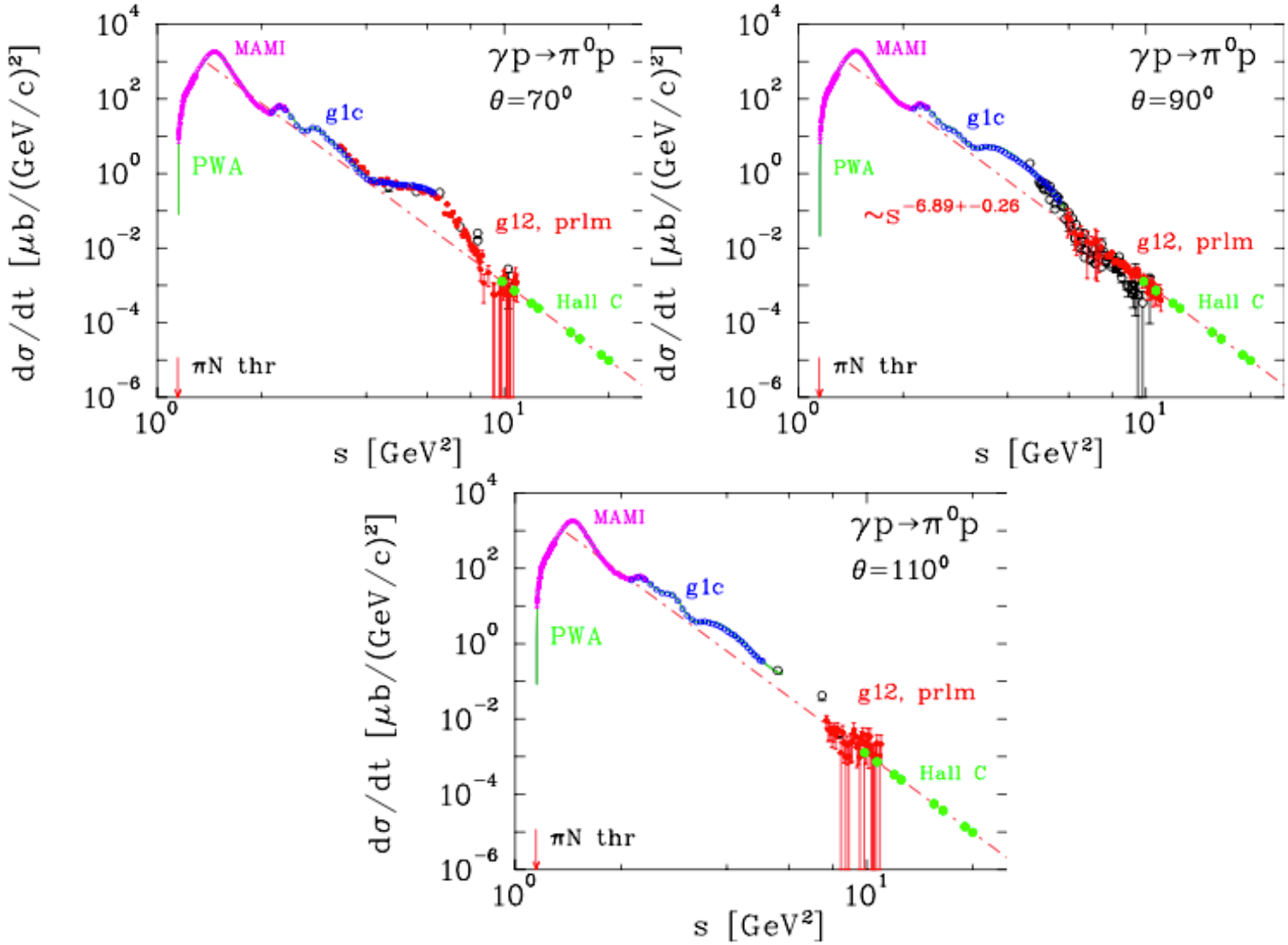


Figure 12: Schematic of the setup (kinematics 5A) at 10 GeV with the HMS detecting the recoil protons and the photon calorimeter detecting the Compton-scattered photons, in addition to a fraction of elastically scattered electrons which will be partly removed by the deflector magnet.

π^0 production in Hall C projected results

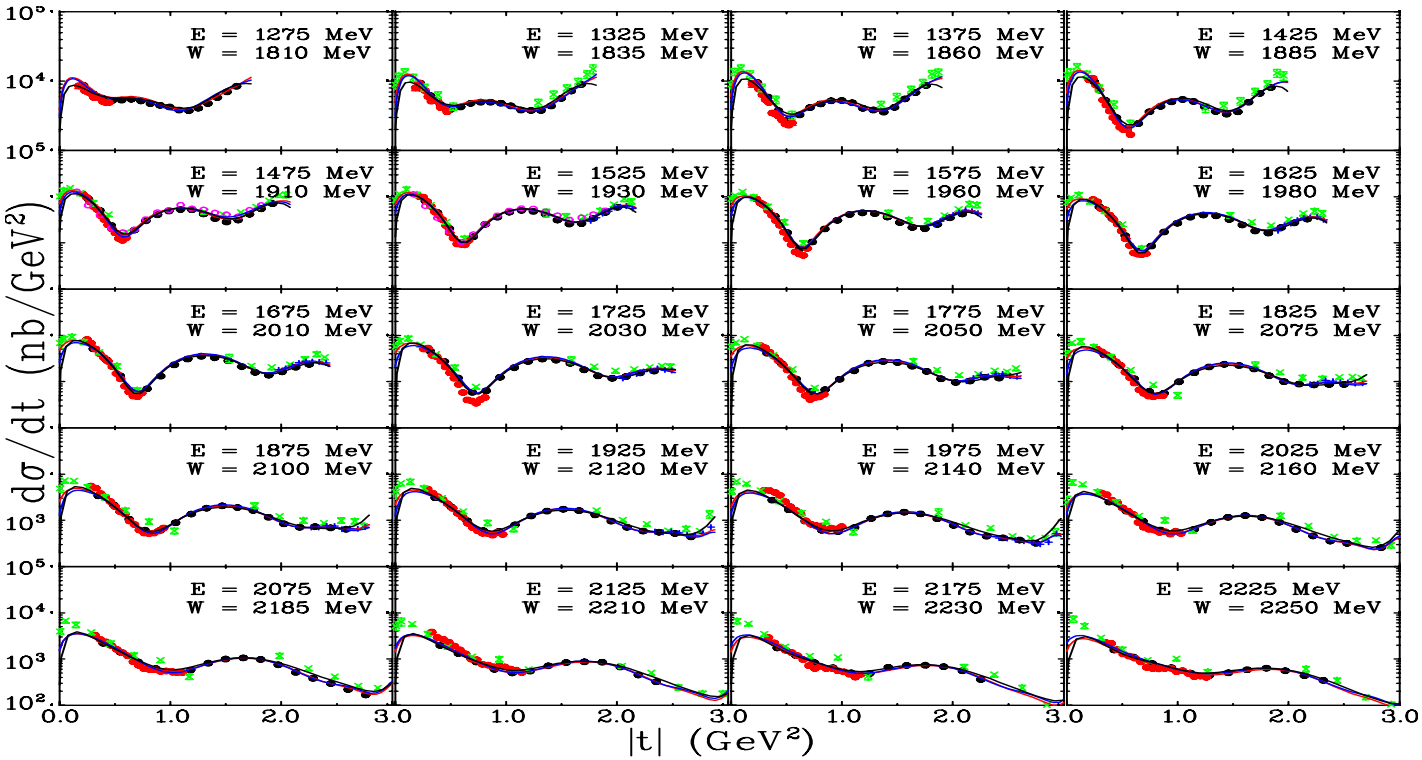


Summary

- π^0 cross-section results in energy ranges previously measured and also not previously measured
  - Measured cross-section agrees well with previous data
  - Regge Model agrees well with data at higher beam energies
- Measurement of π^0 cross-section in CLAS from 6.5 - 10.5 GeV (quasi-real photon beam) will be a byproduct of future transition form factor measurement (pending proposal approval)
  - Further validate Regge model
- PAC approved proposal in Hall-C to investigate s^7 scaling for π^0 and measure π^0 cross-section at specific angles

Stop

t vs. dσ/dt / E_γ = 1.275-2.225 GeV



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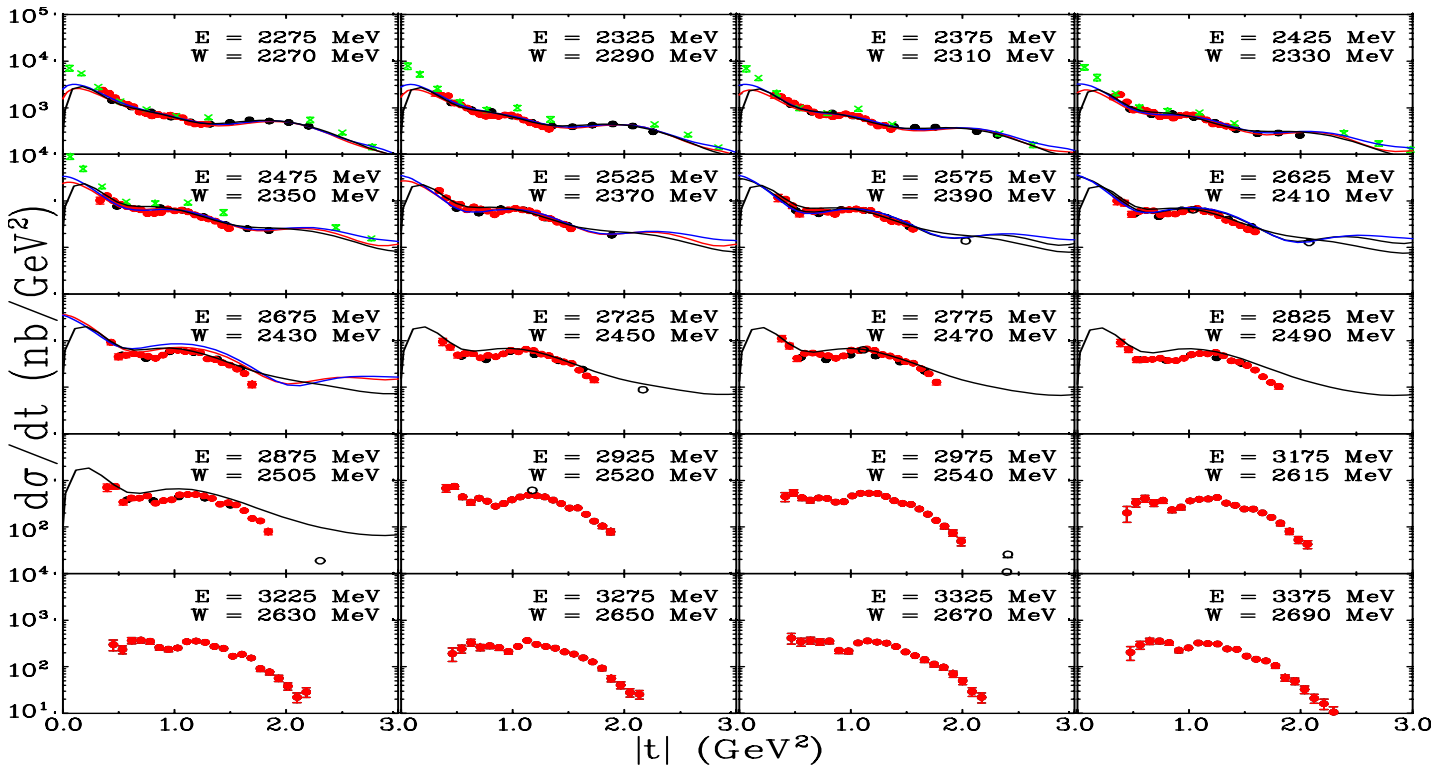

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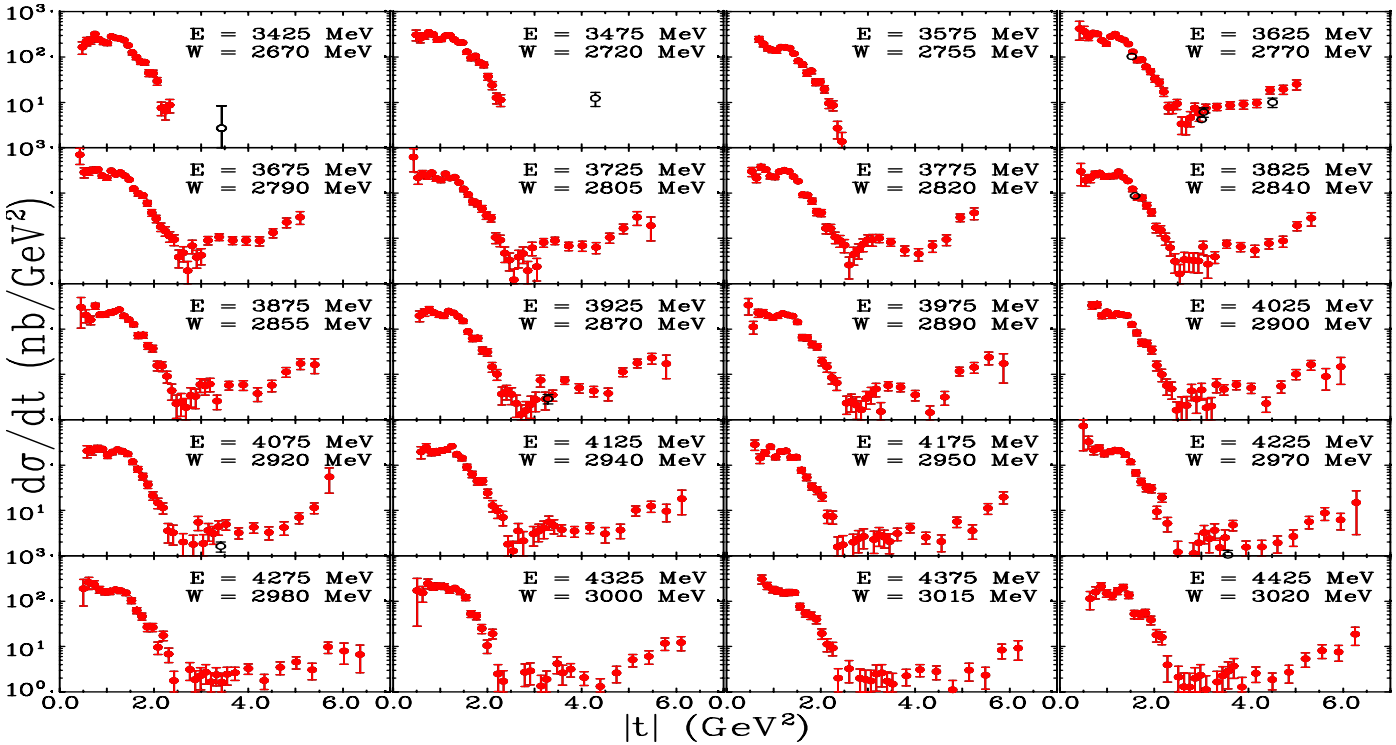

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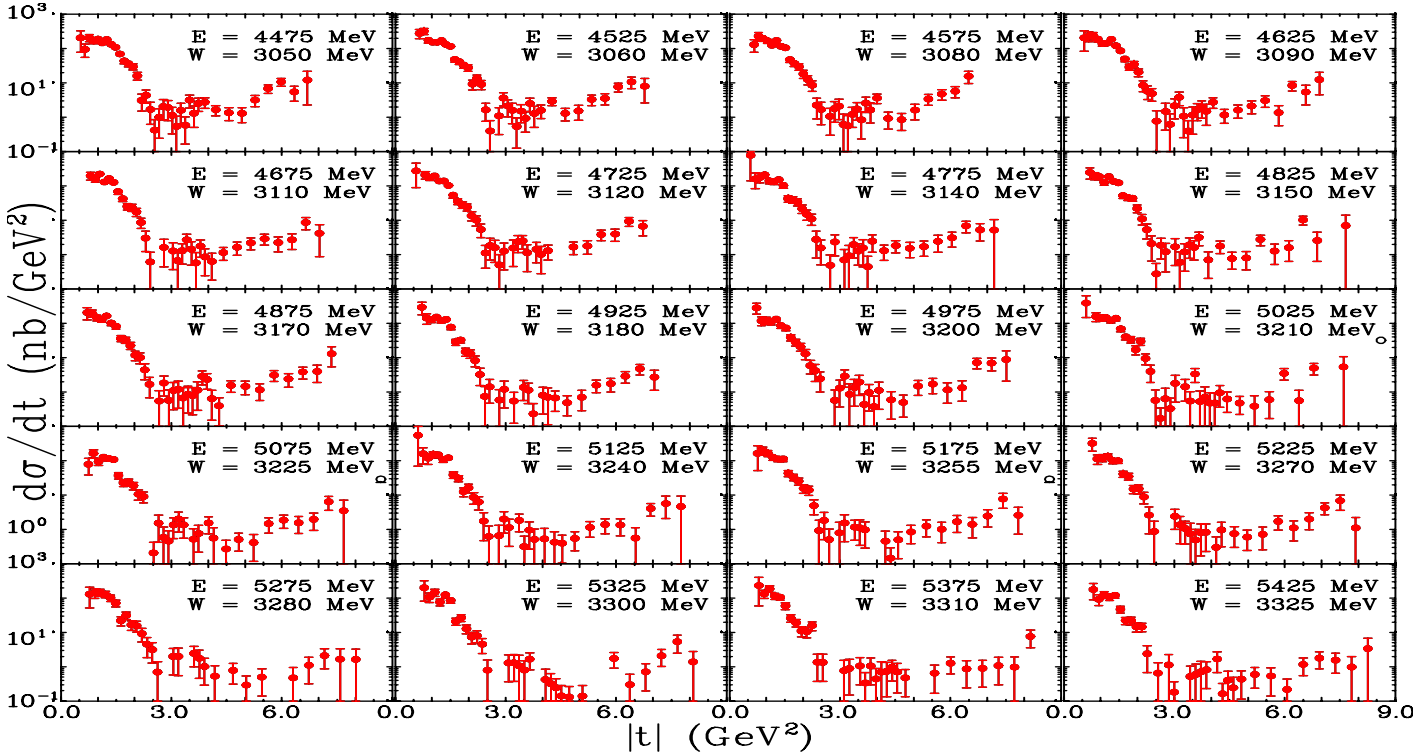
t vs. dσ/dt / E_γ = 4.475-5.475 GeV



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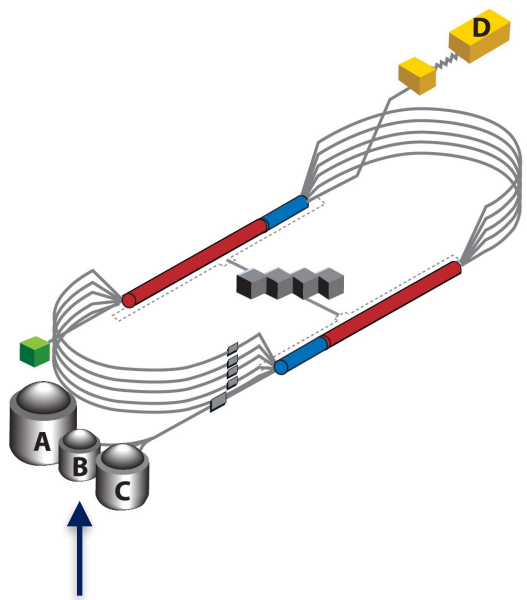
Thomas Jefferson National Laboratory



CLAS

Continous Electron Beam Accelerator Facility (CEBAF) at 12 GeV

Aerial View

Photon Beam

- e^- electron beam impinged on
- Au 10^4 radiation lengths
- Bremsstrahlung photon beam
- Tagged γ energies 1.1 - 5.5 GeV
- 6.2 mm diameter collimator 537 cm before ℓH_2 target

Target

- Liquid Hydrogen (ℓH_2) target
  - Unpolarized
  - 40 cm in length
  - 2 cm in radius
    - γ beam had 1.5 cm radius exiting ℓH_2 target
  - Placed 90 cm upstream from CLAS center
    - Geometric acceptance changed in lab frame
      - 6° from 8°
      - 100° from 140°

e^+e^- Identification

- Cherenkov Counters filled with perflourbutane C_4F_{10}
  - Index of refraction 1.0015
  - $\pi^\pm$ threshold of 2.7 GeV
  - $e^\pm$ threshold of 9 MeV
    - $e^\pm$ detection efficiency > 97%

e^+e^- Trigger

- $e^{\pm}$ trigger
  - (ST*TOF)(EC*CC)
  - L2 multiplicity of 2
  - 2 tracks in drift chamber

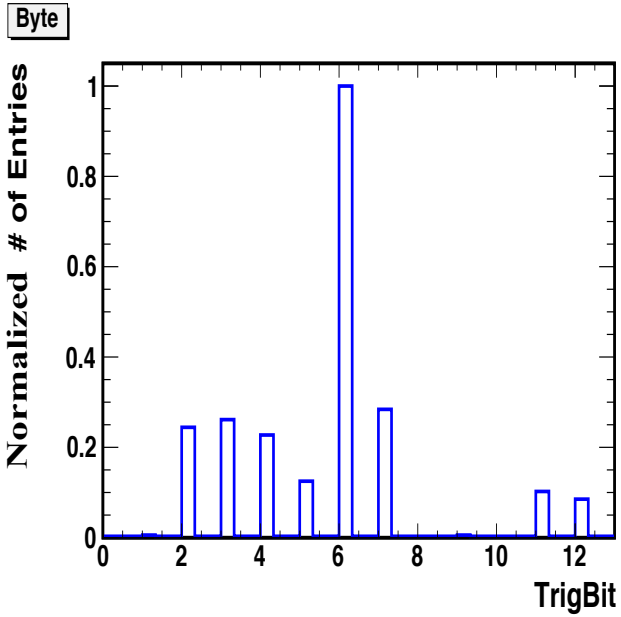
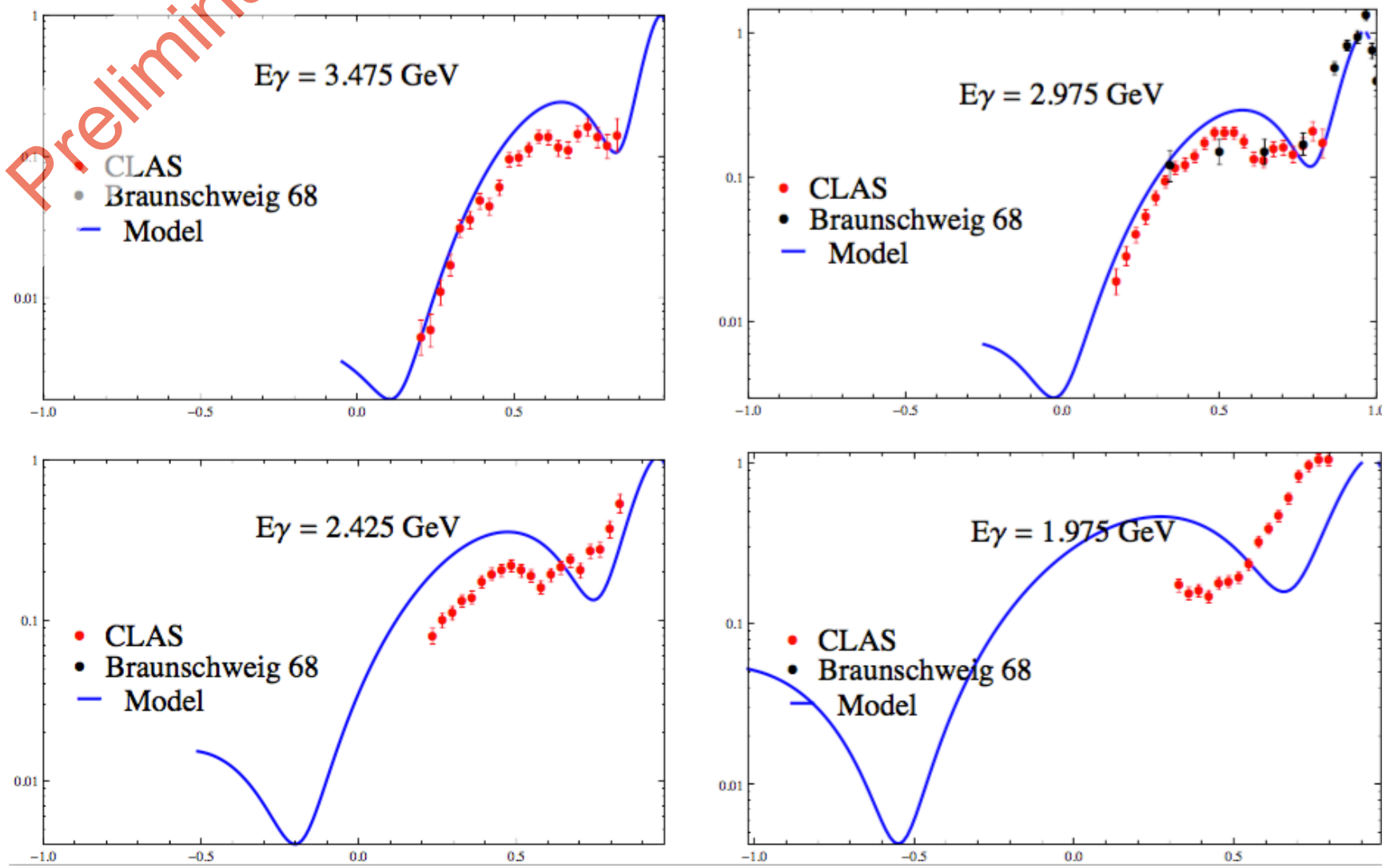


Figure : Triggers fired for leptons

VM Model http://arxiv.org/pdf/1505.02321.pdf



Systematics

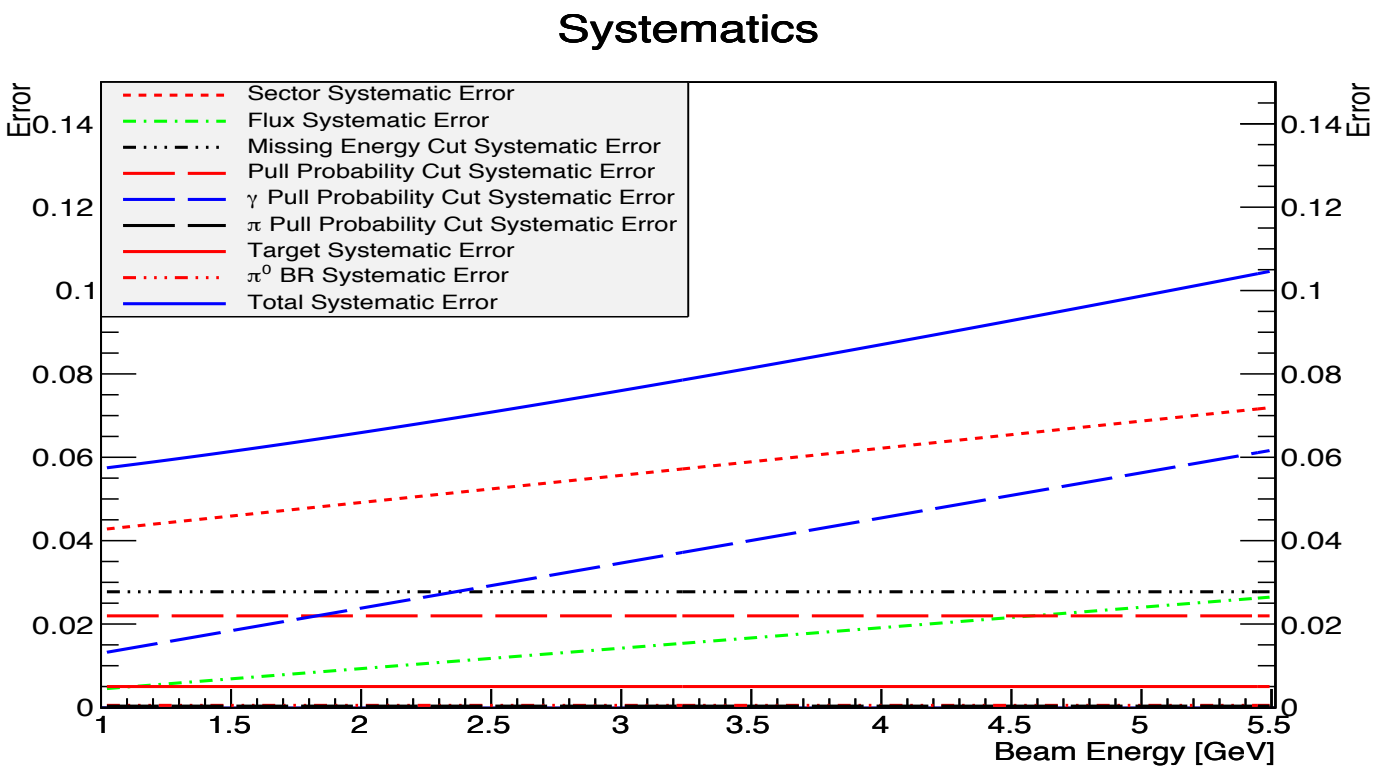
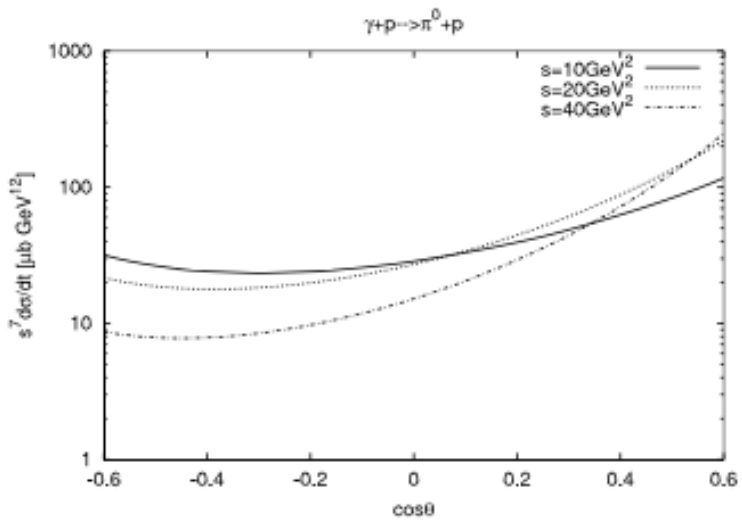
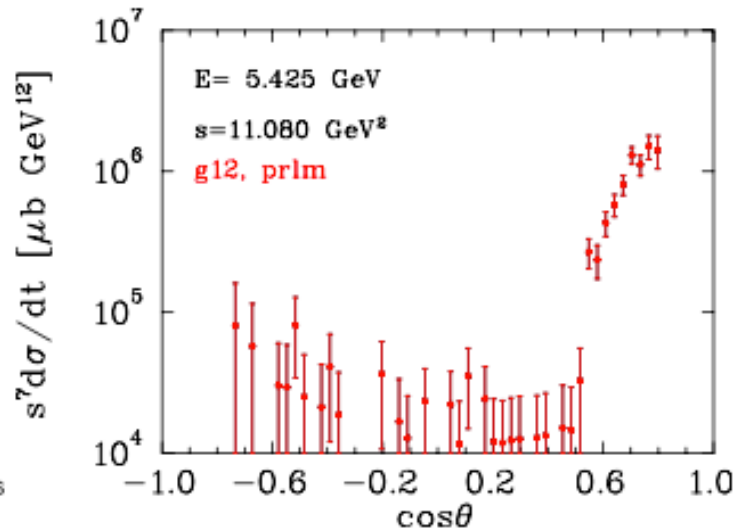


Figure : Plot showing the contribution of the all systematic errors as well as the combined which was calculated adding all systematic errors in quadrature.

Hand bag model





Differential Cross-Section

$$\frac{d\sigma}{d\Omega} = \frac{N_{\pi^0 \to e^+e^-\gamma}}{\epsilon} \frac{1}{\Phi \rho_t} \frac{1}{\frac{\Gamma_{\pi^0 \to e^+e^-\gamma}}{\Gamma_{total}}} \frac{1}{\Delta\Omega}$$

ϵ is the $\pi^0 \to e^+e^-\gamma$ acceptance for the c.m. angle

$\frac{\Gamma_{\pi^0 \to e^+e^-\gamma}}{\Gamma_{total}}$ is the branching ratio of the Dalitz decay

Φ is flux

ρ_t is target areal density$[g/cm^2] =$
$(2. \ / \ 2.01588) \cdot 0.0717 \cdot 40.$

$\Delta\Omega = 2\pi\Delta\cos\theta$

arXiv:1505.02321v1 [hep-ph] 9 May 2015

Neutral Pion Photoproduction in a Regge Model

V. Mathieu*
Center for Exploration of Energy and Matter, Indiana University, Bloomington, IN 47403 and Physics Department, Indiana University, Bloomington, IN 47405

G. Fox
School of Informatics and Computing, Indiana University, Bloomington, IN 47405, USA

A. P. Szczepaniak
Center for Exploration of Energy and Matter, Indiana University, Bloomington, IN 47403 Physics Department, Indiana University, Bloomington, IN 47405 and Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA

(Dated: May 12, 2015)

The reaction $\gamma p \to \pi^0 p$ is investigated in the energy range above the resonance region. The amplitudes include the leading Regge singularities in the cross-channel and correctly describe the differential cross section for beam energies above 4 GeV and for momentum transferred above -3 GeV^2. The energy dependence of the beam asymmetry and the reaction $\gamma n \to \pi^0 n$ seem is quantitative consistent with the Regge-pole dominance.